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REVIEW

Augmented reality for story-related activities in primary and secondary education: a systematic review

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Abstract
Story-related activities such as storytelling, story creation and narrative-based learning have become a popular pedagogical approach used in education. Additionally, Augmented Reality (AR) is a tool that receives significant attention globally. Recognizing this trend, researchers have been seeking ways to integrate story-related activities with AR in educational contexts. This paper presents a systematic literature review focusing on the use of AR in story-related activities within primary and secondary education. By conducting a systematic search of studies published in the past 5 years between 2019 and 2024, 264 relevant papers were initially identified. After applying inclusion, exclusion and quality criteria, 39 studies were selected for in-depth analysis. Framed by the principles of learning experience design, this review explores how AR is integrated into story-based educational practices, highlighting its current applications, benefits, and barriers. Additionally, the review critically reflects on the need to prioritise pedagogy over technological features when designing AR-enhanced learning experiences. The study concludes with recommendations for future research and practical insights for educators aiming to incorporate AR into story-related educational activities.

Keywords Augmented reality (AR) · Stories · Storytelling · Narratives · Research synthesis · Learning design.

1 Introduction

Story-related activities, including educational digital storytelling, story creation and narrative-based learning are recognized as powerful approaches to technology-enhanced learning [1]. Story-related activities refer to a form of human communication that utilises creating, interpreting, or exploring narratives as a means to value and share people's knowledge [2–4]. Story-related activities in education emerge as an essential pedagogical tool encompassing both

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a social pedagogy and a genre of multimodal writing [5, 6] that is aligned with contemporary educational practices that promote student-centered learning [7–11].

1.1 Story-related activities in education

Unlike conventional story-related activities, digital stories leverage the art of telling stories with a variety of multimedia elements, including images and audio. Digital storytelling activities have introduced innovative ways for learning. For example, multimedia, mixed-media, smart objects or educational robotics expand opportunities to craft interactive stories that combine text with images, audio, and video and create multimedia experiences that can enhance the educational process [4, 8, 12, 13]. Regarding the benefits of digital story-related activities, researchers claim that they allow more space for collaboration as students work in groups to develop their stories [14, 15], higher levels of engagement and motivation [16, 17], improvement of digital, informational, oral, written, and visual literacies, and development of 21st century skills such as digital literacy, critical thinking and creativity [18–26].

There is a considerable body of research on story-related activities in education. Existing reviews on story-related activities aimed to trace emerging practices, evaluate the impact and effectiveness of such activities, and explore educational technology implications. For example, Wu and Chen [1] conducted a systematic review focusing on educational digital storytelling (EDS) arguing that EDS is implemented across educational levels and subject areas, either as a stand-alone pedagogy or in combination with other pedagogies, with a focus on humanities and social sciences, especially language and literacy. Their analysis demonstrated positive outcomes, including improvements in affective engagement, cognitive thinking, conceptual understanding, academic skills, technological proficiency, linguistic abilities, and social skills. The study of [27] also presented a systematic review that focused on the outcomes of digital storytelling and emotional relationship. Results demonstrate that digital storytelling entails potential in enhancing engagement, empathy and self-awareness. In their systematic review, Quah and Ng [8] focused on digital storytelling authoring tools and highlighted the rapid increase in the use of emerging technologies for story-related activities in education. The authoring tools were categorised into web-based, desktop, mobile, mixed-platform, tangible user interface, virtual reality, augmented reality, embodied enactment, wearable, and robotic applications. A more recent scoping review by [4] brought together storytelling and educational robotics (ER) demonstrating the use of storytelling mainly in secondary and university education and highlighting the use of ER as a contemporary educational tool to support knowledge gain and develop useful skills. Thus, even though story-related activities have a long history as a pedagogical approach in educational settings, contemporary educational technologies come to inform their use for creating engaging and impactful learning experiences.

1.2 Augmented reality for story-related activities

Augmented Reality (AR) refers to technologies that superimpose digital material, such as images, audio, and video, on real-world objects [28]. The use of AR is supported to have a promising future in learning as educators around the world look for new, creative, and engaging ways to capture students' attention [29–31]. The study of [32] showcased the increased interest of AR in education evidenced by both the scientific production in the last 5 years and the large volume of citations received by the manuscripts that focus on this topic.

Recent reviews investigating the trends of authoring tools in educational digital storytelling show a recent shift towards incorporating physical prototyping and AR tools alongside traditional media [8]. By superimposing digital content into the real world, AR enables students to bring their stories to life by visualising and placing their narrative in the physical space [8, 10, 33–36]. Empirical studies that examined the use of AR applications with story-related activities reported positive findings on student's creativity, user engagement, interest and sense of immersion due to the visual perspective provided by AR environments, highlighting AR as a promising avenue in story-related activities [34, 35, 37–39]. In this context the study of [40] examined the characteristics of student-created AR artifacts, scenes and storylines within CoSpaces, a popular learning tool with an extensive library of 3D models. Their study identified key benefits, including improved language comprehension, research skills, and digital literacy. The platform's user-friendly interface and diverse features empowered students to express themselves creatively, collaborate with peers, and connect with real-world experiences.

1.3 Research gap

The rapid evolution of technology offers innovative ways to create dynamic and engaging learning environments. By integrating cutting-edge technologies such as AR in story-related activities, educators can advance their teaching practices and bring students' stories to life. Considering this progress, the question arises regarding the didactic potential of AR-driven story-related activity, and more specifically its pedagogical and practical implementation in teaching, which has not yet been thoroughly examined. Although previous reviews have significantly contributed to the literature

on AR and story-related activities, there are still two key issues that have yet to be addressed. Firstly, existing review studies [e.g., 1, 10, 18, 27], have mainly focused on these areas separately or in broader contexts. This systematic review specifically examines how AR-based story-related activities are integrated within primary and secondary education, and consolidates fragmented findings in order to provide educators, researchers, and policymakers with a unified understanding of how AR-based story-related tasks can enrich language learning experiences. The inclusion of primary and secondary education in this review is justified by the continuity in cognitive and developmental characteristics across these stages, which allows for a comprehensive understanding of the interplay between AR technologies and story-related practices across different educational contexts. Secondly, previous reviews have not sufficiently addressed the pedagogical implications of AR-based story-related activities. This study fills this gap by providing a focused analysis of recent literature, critically addressing how AR-based activities can support effective teaching and meaningful learning experiences and eventually provide good learning design practices in the use of AR for story-related activities (e.g., story creation, storytelling) in different content domains.

1.4 Objectives

This review offers two key improvements with regard to AR-driven story-related activities in learning: first, it delves deep into the design of story-related learning experiences with the use of AR to directly understand what works well in the design of such experiences and second, it contributes by providing future directions for research and practice focusing on learning design practices. That said, by understanding the key learning design elements in the use of AR for story-related activities, this review can inform the design of learning experiences and provide practical implementation of classroom interventions with this technology.

This work adopts the "Trinity of learning design" framework by [41] to address the "Tools", "Techniques", and "Ingredients" as the intersecting aspects of learning design, namely learning design for AR learning experiences. The adoption of this framework was motivated by its ability to consider pedagogical approaches, teaching materials, and content concurrently. Additionally, it is a recent pedagogical framework that forms a comprehensive approach to education. It supports effective teaching and meaningful learning outcomes that are also adaptable to the changing demands of students and society. Per this framework, 'techniques' include all pedagogies and approaches to teaching and learning, 'tools' refer to all materials and tools to be used, for instance, books, computers, robots, etc., and 'ingredients' include the content domain, learning objectives, feedback, etc. Given the importance of these elements in learning design, this review aims at extracting these elements from the currently published work and, therefore, presenting evidence-informed practices to practitioners and researchers. Overall, using the "Trinity of Learning Design" framework, as discussed by [41], this study explores the current practices of learning design pertaining to the use of AR for story-related activities in primary and secondary education. This will be the first study that follows a systematic approach to exploring the use of AR in story-related activities in education by providing deeper insights into the elements of the interventions conducted (tools, techniques and ingredients). The aim of this review is to provide both educators and researchers with good learning design practices for implementing relevant interventions and studies.

The following research questions (RQs) guide this work:

RQ1: What are the current practices of learning design in terms of "Tools", "Techniques", and "Ingredients" pertaining to the use of AR for story-related activities in primary and secondary education?
RQ2: What barriers come with the adoption of AR for story-related activities in primary and secondary education?
RQ3: What are the benefits of using AR for story-related activities in primary and secondary education?

2 Methodology

This systematic review followed the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement by [42], because it ensures a comprehensive, and standardized approach to reporting systematic reviews. In order to assist authors in creating an open, thorough, and accurate description of the review's purpose, methodology, and findings, the PRISMA 2020 statement also includes a checklist with reporting guidelines and updated flow diagrams for both original and updated reviews [42].

2.1 Searching the literature

A search was conducted in three major databases for science and education (Scopus, Web of Science, and ERIC). The query string included keywords that derive from the definitions of AR, story and education (e.g., Augmented Reality, AR, Mixed Reality, XR, children, primary education, secondary education, K12, story*). The query string used for searching the databases was: ("Augmented Reality" OR "AR" OR "Mixed Reality" OR

Table 1 Search results

Database	Notes	Results
Web of Science	Topic search Past 5 years	27
Scopus	Title-abstract-keyword search Past 5 years	55
ERIC	Peer-reviews only Abstract search Past 5 years	78
Google Scholar	Past 5 years First 10 pages	100
Snowball technique	Snowballing of relevant studies	4
Total search results		**264**

"MR" OR "Extended Reality" OR "XR") AND ("learning" OR "teaching" OR "course") AND ("children" OR "primary education" OR "secondary education" OR "K-12") AND ("story*"). It is important to highlight that the term "stories" -searched as "story*"- in the current work, aimed to capture studies around all kinds of story-related activities, including story creation, narratives, storytelling, and/or fairytales as identified in the literature in all educational domains. Aiming to identify recent work concerning the implementation of AR within primary and secondary education, the search was conducted for papers published within the past 5 years (2019–2024). The last search was conducted on March 4th, 2024, and returned a total of 160 papers from all three databases. Additionally, Google Scholar search was performed as a strategy to further expand the pool [43, 44], with the first 10 pages of the results being reviewed following [43, 45]. This search returned 100 results in the first ten pages. We further identified papers using a snowballing technique [43], where citations in other papers were considered for inclusion. Four (4) additional papers were identified through snowballing. Therefore, a number of 104 additional papers were added through these methods, resulting in a total of 264 papers being identified. The results derived from each method are presented in Table 1.

2.2 Screening for inclusion

Of the 264 papers returned from the three databases and additional papers via other methods, 24 papers were removed as they included duplicated papers, resulting in 240 papers eligible for the first screening. One researcher reviewed the titles and abstracts of all the papers and excluded 92 papers due to their irrelevance to the topic. Five papers could not be retrieved and were therefore excluded. This resulted in a total of 143 papers being retrieved, 48 from the databases and 95 via other methods. The process of identification, screening, and inclusion of the literature is depicted using the PRISMA flow diagram as from [46], as in Fig. 1.

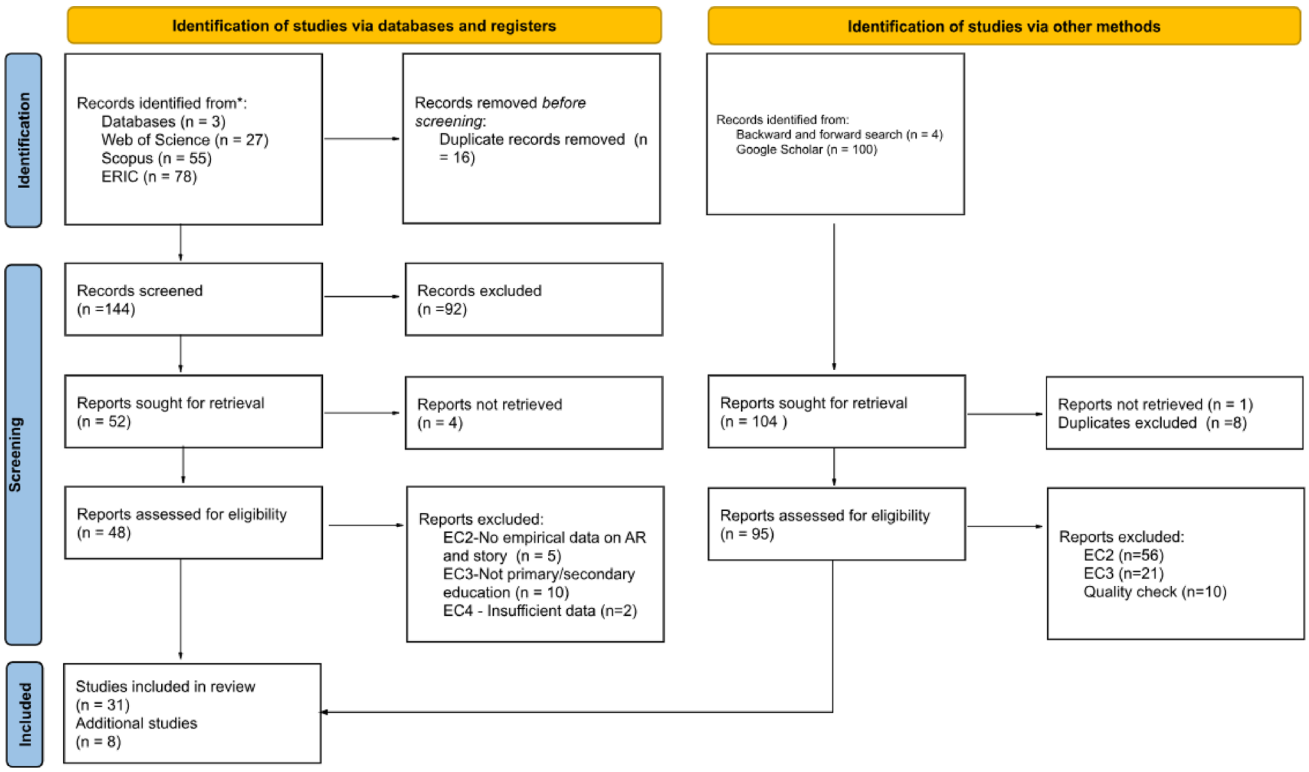

Fig. 1 PRISMA flow diagram

Table 2 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. The manuscript should have been published between the years 2019–2024	1. The manuscript was published before 2019
2. The manuscript should involve empirical data on the design and implementation of AR as an educational tool in story-related activities. The term "stories" in the current work refers to story-related activities, including story creation, narratives, storytelling, and/or fairytales as identified in the literature in all educational domains	2. The manuscript didn't aim at constructing AR, that is, showing the design, development, usability or interface efficiency of AR or does not include empirical data
3. The manuscript should present AR as an educational tool for stories (story creation, storytelling, etc.) for primary or secondary education	3. The manuscript involved AR as a teaching tool in education in general with no (or poor) reference to story-related activities for primary or secondary education
4. The manuscript presented sufficient data to identify practices and barriers related to the use of AR for story-related activities (story creation, storytelling, etc.) in primary or secondary education	4. The manuscript did not involve sufficient information and was composed of only one page (abstract papers), poster, presentations, scientific events program, tutorial slides, literature reviews, book reviews or editorials
5. The manuscript was peer-reviewed	5. Non-peer-reviewed resources (grey literature) were excluded from the dataset
6. The manuscript was written in English	6. The manuscript was written in a language other than English
7. The manuscript should be accessible	7. The manuscripts couldn't be accessed

2.3 Inclusion and exclusion criteria

Of the 143 papers assessed as eligible to be included in the current review, 94 papers were excluded after the application of inclusion and exclusion criteria (see Table 2). More specifically, some papers did not provide empirical data on the use of AR (EC2, $n=61$), referred to the use of AR in levels of education other than primary or secondary education (EC3, $n=31$) or presented insufficient data on the use of AR for story related activities (EC4, $n=2$).

2.4 Quality criteria

To ensure quality, only peer-reviewed manuscripts were included. All publications that did not provide sufficient data to address the research questions were excluded [47]. Additionally, to ensure quality and credibility of papers extracted from Google Scholar, we verified that the journals in which the papers were published ranked in Quartile 1 (Q1) or Quartile 2 (Q2) according to the Scimago Journal & Country Rank (SJR). A total of 10 papers were excluded after quality control, resulting in a total of 39 studies being included and thoroughly examined in the current review.

Table 3 Data extracted from papers

Publication identification	RQ1	RQ2	RQ3
IE1: Author IE2: Publication Year IE3: Title IE4: Source IE5: Abstract IE6: Level of education	IE7: Description of AR story Activity Design (a) Techniques (b) Tools (c) Ingredients	IE8: Barriers to AR implementation	IE9: Benefits AR for story-related activities

Table 4 Overview of the "Trinity of learning design" framework by [41]

	Description	Example
Tools	Include all materials and tools to be used for teaching and learning	Computers, mobile devices, robots etc.
Techniques	Include all pedagogies and approaches to teaching and learning	Computer supported learning, collaborative learning, games/simulations etc.
Ingredients	Include the content domain, learning objectives and feedback	Language, mathematics, science etc.

2.5 Data extraction and synthesis

Following the approach of [48], from each chosen paper, 10 items were extracted (IE) (see Table 3). These items provided important information to answer the RQs, perform the synthesis and validate the quality standards. These items were categorised per the study's research questions, in addition to identification details.

The "Trinity of Learning Design" framework by [41] was used to structure data extraction and synthesis within RQ1. More specifically, data for RQ1 was extracted and synthesised into "tools," "techniques," and "ingredients" as the intersecting aspects of learning design, in this case learning design for the use of AR in story-related activities (see Table 4). Per this framework, 'techniques' include all pedagogies and approaches to teaching and learning, 'tools' refer to all materials and tools to be used, and 'ingredients' include the content domain, learning objectives and feedback [41].

3 Findings

3.1 Current practices of learning design in terms of "Tools", "Techniques", and "Ingredients" pertaining to the use of AR (RQ1)

The findings of the RQ1 were organised in terms of "Tools", "Techniques", and "Ingredients" of learning design pertaining to the use of AR for story-related activities in primary and secondary education, based on the "Trinity of Learning Design" framework [41].

3.1.1 Techniques

"Techniques" included the theories and pedagogical approaches to teaching and learning. Table 5 presents the most persistent theoretical and pedagogical approaches identified in the literature, as elaborated below.

In terms of theoretical approaches, *constructivist and constructionist learning* were widely adopted in AR for story-related activities encouraging active engagement and construction of AR stories. For example, in the study of [49], children with autism spectrum disorder (ASD) arranged and constructed social storyboard cards in various social story plots through AR. Similarly, in [50], students actively constructed tutorials and interacted with museum exhibits with the use of AR, enhancing their understanding of historical contexts.

Situated learning was another theoretical approach framing previous works, based on the premise that AR offers experiences that anchor knowledge in real-world places. For example [51], followed a place-based approach where they created 3D and 2D objects based on schoolyard pictures.

In terms of pedagogical approaches, *spiral learning* emphasises that a learner's comprehension of the basic ideas of a subject should get deeper as they learn to use them in new and more complicated ways. For example, in the study of [52], students collaboratively created interactive AR multimodal and storytelling artifacts in various phases with increasing degrees of complexity.

Another pedagogical approach followed in the studies, included the *Universal Design for Learning (UDL)*, which prioritizes the accessibility of all learners when it comes to the design of a content delivery system. In the context of UDL, the study of [53], used a serious alternate reality game enhanced with AR as an innovative multimodal method for formative assessment. More specifically, they designed a game around a familiar theme and a relatable character (Nemo) to the students, which included oral, written, video instructions, images, and animations to offer multiple representations. It also incorporated formative assessments and digital tools that allow students to design their own game to support varied means of action and expression [54].

Collaborative learning was evident in the dataset, with a focus on group activities that encourage knowledge sharing and peer interaction. For example, in [51], the students were engaged in brainstorming sessions to collaboratively create narratives using 2D and 3D objects. Similarly, in [55], students used AR in pairs or groups of four to access content, they worked together, shared their work and learned from each other.

A *Game-based learning (GBL)* approach as well as *gamification* elements [54], were used as a means to increase motivation and engagement while using AR for story-related activities. For instance, children with ASD in [56], read a tale script with the therapist and looked at an AR coloring

Table 5 Summary of theoretical and pedagogical approaches in research on AR for story-related activities

Theoretical and pedagogical approaches	Description	AR and Story Experience	Indicative literature
Theoretical Approaches			
Constructionism	Enables students to develop and build their own narratives using AR	Students explore, interact, and imagine in nature to create/share their AR stories	[58]
Constructivism	Emphasises hands-on experiences and active engagement with knowledge	Students interact with narratives, storyboard cards and 3D elements through AR	[49, 60]
Situated learning	Learning is embedded into pertinent situations	Students interact with AR content linked with specific places (e.g., schoolyard, museums, heritage sites)	[50, 51, 60]
Pedagogical Approaches			
Spiral Learning	Students progressively deepen their understanding of fundamental concepts by learning to apply them in increasingly complex ways	Students collaboratively create AR multimodal and storytelling artifacts in various phases with increasing degrees of complexity	[52]
Universal Design for Learning (UDL)	Creation of an inclusive content delivery system accessible to all learners	Students in groups played AR story-games, solved the puzzles and created their own story-game	[53]
Collaborative learning	Group activities that encourage knowledge sharing and peer interaction	Students in groups create AR narratives or collaborate to solve problems	[51, 55]
Gamification and Game-based learning (GBL)	Use of game components to increase motivation and engagement	Students interact with different AR games using narratives to solve problems	[57, 61, 62]

book picture, discussed it and colored it while explaining the significance of its social cues. In the same vein, in [57], children with ASD were asked to role play with the teacher to enhance social interaction skills and to also arrange story cards on the storybook in order and according to the storybook. Furthermore, outdoor activities emphasizing imagination [58], object interaction [57, 59] and contextualized activities were examined in the dataset.

In terms of task design, we classified the AR for storytelling in three main educational purposes as suggested by [60] p. 116:

(a) Information transmission activities in which learners access educational material contextually;
(b) Social constructivist activities in which learners individually or in groups record, annotate, interact, modify elements of the virtual or real settings, and;
(c) Constructivist activities in which learners design and build AR artefacts.

Table 6 Task design

	Story-related AR Task	Description	Indicative Examples
Information transmission activities (access educational material contextually)			
1	Accessing AR multimedia story elements	Students individually or in groups scan markers such as QR codes, images, story books to access AR multimedia story elements	[55, 56, 64, 65, 67, 72]
Social constructivist activities (students individually or in groups to record, annotate, interact, modify elements of the virtual or real setting)			
2	Carrying out story-related closed-ended quiz/game/mission	Students interact with multimedia content in AR and then engage with AR gamified quizzes that feature narratives through multiple-choice questions and drag-and-drop activities	[59, 61, 62, 68, 73, 74]
3	Discussion/social interaction with animated 3D versions of the character(s) in the storybook	Students receive AR multimedia content and feedback while they also engage in virtual discussions with virtual characters	[49, 57, 69–71]
Constructivist/ionist activities (learners design and build AR artefacts)			
4	Creating and sharing AR artefacts (e.g., stories, narrations)	Students individually or in groups explore AR story elements, interact, and create or continue stories or narratives in AR	[50–53, 58]

Four main story-related AR tasks were categorized under the three categories (see Table 6). The majority of the tasks used in the studies emphasized information transmission and social constructivist activities. In information transmission, students' main task was to access AR multimedia story elements. More specifically, students individually or in groups scan markers such as QR codes, images or story books to access AR multimedia story elements such as 3D objects (e.g., [56, 61, 62]). For example, in the study of [63], selected Philippine folklore children's stories were augmented with characters and environments available in 3D. Similarly, in [64], students using their tablets scanned a language learning storybook and certain elements begun to appear and move on the tablet screen.

In social constructivist activities, students' main tasks were to carry out story-related closed-ended quizzes, games or missions (e.g., multiple-choice questions, drag-and-drop activities) after interacting with multimedia content in AR (e.g., [65–67]) or engage in discussion and social interaction with animated 3D character(s) of a story-book, while receiving AR multimedia content and feedback (e.g., [49, 57, 68–70]).For example, in the study of [69], participants watched a demonstration animation of bed-making and different cloth outlines of different seasons through an augmented-reality projection tabletop. To learn about regularly used clothes in different seasons, participants were asked to select and place the correct clothing into the projection outlines. Then, they had to move the clothing to the projected character to learn the dressing routine.

Finally, studies found that their tasks were aligned with the constructivist/ionist approach, with learners participating in activities to create and share story related-AR artefacts (e.g., stories, narrations). More specifically, students in groups or individually explore AR story elements, interact, and create or continue stories or narratives in AR (e.g., [50, 51, 58]). For instance, students in pairs captured the story of an AR character in nature using tablets, created and shared their personal stories through AR [58]. Similarly, students collaboratively created AR storytelling artifacts by combining multimodal information such as text, image, video, audio and animation [52].

3.1.2 Tools

"Tools" included the variety of tools and materials used for learning and teaching, including devices and software. A summary of the tools identified is presented in Table 7.

The prevalent for *custom-made AR Software* were "Unity 3D" and/or "Vuforia" (e.g., [65, 71]) , such as for the development of AR storybooks (e.g., [72]). AR content was also developed using other programs, such as "Build AR" [72] and "HP Reveal Studio" software [62]. Software was also

Table 7 Tools used in research on AR for story-related activities

Applications, material, software and devices	Description	AR and Story experience	Indicative literature
Custom-made AR Software	Software to develop custom-made AR apps (Unity 3D and/or Vuforia, Build AR, HP Reveal Studio, Kotlin programming language)	Development of AR content, books or experiences that present or tell a story	[51, 61, 75]
3D Character Software	Software to build 3D character models and body movements (e.g., iClone 3D and Maya)	Development of 3D character models for use in AR stories	[57, 66]
AR mobile applications	Applications for AR experiences such as MyAr Julle, FAnTASIA, Blue Planet Tales app, Augment	Use of AR mobile applications as digital storytelling, visualisation and colouring tools	[56, 58, 59]
AI-powered AR app	AR app that integrates artificial intelligence (AI) to support students in their interaction	A smart book AR assistant application using 3D characters to explain lessons with sound	[69]
Mobile or other hand-held devices	Mobile or other hand-held devices such as smartphones and tablets as means of interaction with the AR stories	Students use mobile devices to interact with the AR story-related activities (e.g., scan, create, manipulate AR elements)	[56, 64, 74]
Markers (e.g., QR codes, images, flashcards, storybooks, physical objects)	Scannable markers such as QR codes, flashcards, storybooks or images as a means to access story-related AR multimedia content	Students use their device camera to scan markers and access or create AR multimedia story-related content such as scenes, characters, museum exhibits, and narratives	[50, 55, 57, 65, 68, 75, 78, 79]
Marker-less AR	Mobile marker-less tracking and sensors for accessing and interacting with AR content	Students use sensors, facial tracking and Kinect technology to interact with AR elements and characters	[71, 79, 80]

used for *3D character building* and body movements such as "iClone 3D" and "Maya" [57].

Besides, a variety of *AR mobile applications* for story-related activities were used among the studies. Examples include "MyAr Julle" AR application that was used as a digital storytelling tool in the study of [58], and the "FAnTASIA" mobile application in the study of [59], that allowed students to visualize and test realistic environments. Moreover, the "Blue Planet Tales" application was used for AR story creation in the study of [73], while an AI-powered AR application with a 3D smart book AR assistant that explain lessons with sound was used in [68].

Mobile or other handheld devices such as smartphones and tablets were the most popular devices used for AR applications (e.g., [61, 71, 74]). Students were provided with mobile devices from their schools that were prepared in advance to access AR content [50]. Students in [55], were provided with a tablet, which they used to scan prototypes during the storytelling process, which were linked to the story topic (e.g., the Argo ship or the Acropolis).

Marker-based AR was used to initiate the interaction with the AR content in various studies. This involved learners scanning markers such as QR codes, pages of a storybook, images or even physical objects with their mobile devices, in order to access and interact with AR the content [55, 71, 75]. For instance [59], used target images in AR situations, with users activating different scenarios by scanning selected photographs from a fairy tale. The study of [76], referred to the design and implementation of AR-enhanced storybooks as the primary tool for delivering educational content especially for children. On the other hand, Zuo et al. [61] used an AR Storybook application and preferred the use of AR-based texts from textbooks, instead of storybooks as reading materials.

Moreover, *marker-less AR* interaction with motion sensors was also noted (e.g., [77]), as well as facial tracking and enabling the embodiment of a character (e.g., [78]). Kinect technology was used in the study of [70] to help children with ASD improve their social interaction through observing and responding to the movements of virtual characters in AR contextual scenes (e.g., family group, classroom).

3.1.3 Ingredients

"Ingredients" refer to the content domain, learning objectives, and feedback that pertain to the use of AR for story-related activities. Both formal education activities, which typically take place in school, and informal education activities that happen outside the school, such as museum visits, were revealed. Table 8 presents an overview of the main content domains identified in this review.

The use of AR for story-related activities was evident in various content domains, including *mathematics* [65, 66], *culture* [55], *chemistry* [74, 79], *science* [59], and *sex education* concerning touching, body boundaries, and consent [80]. For example, Danaei et al. [65], created AR storybook games focused on learning English and mathematics. On the other hand, chemistry elements and chemical reactions were taught using AR and stories in [74]. When it comes to culture (that also includes history, mythology, and other social sciences e.g [55]), an example is the study of [50], where AR stories incorporated into museum exhibits to

Table 8 Main content domains identified through the literature

Content domain	Description *AR story related activities were used to:*	Indicative literature
Mathematics	Teach mathematical concepts	[61, 62]
Language learning	Improve or practice language learning, enhance vocabulary learning and retention, improve shared reading, assess reading comprehension	[64, 69, 73, 75]
Culture	Promote cultural awareness, history, mythology and other social sciences, e.g., explore historical narratives, etc.	[55, 76, 78]
Chemistry	Teach chemistry elements and chemical reactions	[74, 77]
Science	Teach scientific concepts and skills	[59]
Sex education	Teach about touching, body boundaries and consent	[81]
Special education	Develop social skills for children with ASD	[56, 57, 70, 80]
Storytelling and digital narratives	Teach storytelling as a content domain	[33, 83]

allow students to explore historical narratives related to the exhibits. Moreover, AR books were used to provide tangible experiences for students to enjoy and preserve traditions and life scenes (e.g., the mountain of Psiloritis in Crete as described in [72]).

The use of AR and story-related activities for various aspects of *language learning* was of high interest among the studies (e.g., [65, 68, 73]).*Vocabulary* learning, improvement and retention was highlighted in the studies as an aim of using stories with AR [55, 67, 71]. A good example can be found in the study of [67], where students followed the plot of a short story and filled in parts of its sentences by searching the surroundings for the appropriate word. Enhancing literacy skills, such as *reading comprehension*, was also found to be the main focus of some studies that used AR applications for stories (e.g., [61, 62, 68]). Studies also examined AR to improve shared reading (e.g., between students and parents in [81]).

Special education was another domain of interest. Namely, *social skills* have been examined in multiple studies, specifically for children with ASD. For example Hsu and Lee [57], used AR to support children with ASD in developing social reciprocal behaviors within specific social contexts using stories, while the study of [56], using an AR coloring book, aimed to teach children with ASD how to better comprehend and focus their attention on the meaning and social value of greeting behavior in specific social situations. Moreover the study by [69], combined AR with storytelling to support training children with autism in daily living skills. Similarly, the purpose of the research work presented in the study of [49] was to support children with ASD to develop more flexible reciprocal social behaviors and social relationships in different situations by having them organize cards on blank storyboard maps according to a social story, aiming to improve their social skills, while the corresponding social animation was presented through AR.

In the papers reviewed, *storytelling and digital narratives* appeared as a content domain independent from typical school content domains. Several studies have focused on storytelling as a content domain in different learning contexts. For instance the study of [82], focused on storytelling for the creation and application of AR-enhanced stories for children receiving cancer treatment. The use of storytelling was highlighted in their study as a psychoeducational tool by addressing how it was incorporated into the project's learning objectives and feedback processes. Similarly the study by [51], used AR and a place-based approach to teach storytelling to rural primary school students. In other cases, storytelling was used as a means to improve communication and collaboration skills, as well as to foster creativity and memory retention. For example, in the study of [33], students had to narrate stories and develop their own to explore the impact of virtual and physical interactions on storytelling and story building. Moreover, the study by [63] emphasized the synchronization of visual and auditory elements in AR storytelling, enhancing the narrative experience by creating a rich, multimodal environment that supports better comprehension and retention of the story content. Story crafting in nature was highlighted in one study that used an AR application as a digital storytelling tool for children, allowing them to explore, interact, place AR characters in nature, and create/share their stories [58]. Moreover, AR was used as a means for an after-school program that aimed to develop elementary school students' digital literacy through the creation of AR storytelling and multimodal artifacts [52].

AR provided students with feedback mechanisms, rewards, and scores concerning the accuracy of their answers (e.g., [55, 66, 68]). For example, message and sound feedback was provided to students when they selected incorrect answers and they could try again [74]. Similarly, AR animated feedback to depict the correct social reciprocal behavior was provided to students with ASD who practiced social and daily living skills [57].

3.2 Barriers to the adoption of AR for story-related activities (RQ2)

Implementing AR technology in educational settings presented several barriers that hindered its widespread adoption. These barriers encompassed various aspects, ranging from technical difficulties to pedagogical concerns. Table 9 presents the identified barriers and details on how they were coded through the manuscripts.

Table 9 Identification and coding of the barriers related to the adoption of AR for story-related activities

Theme	Description	Examples from the reviewed manuscripts
Interruptions	Interruptions of students while engaged with the AR activities	"the teachers interrupted the students in the AR activity to provide instructions or guidance" [33]
AR as a distraction	AR may act as a distraction rather than a learning aid	"the active interaction with AR models may represent a distraction towards following a reading or audio" [73]
AR complexity	Refers to complexity of developing AR content	The study of [57] refers to the use of different software such as "iClone 3D character modeling software" to build 3D social character models, and "Maya" for character 3D social interaction animation as the AR feedback for social interaction content"
Time investment	Time investment is required for AR for story-related activities	The implementation of AR and CT games required a long time period of 3.5 months. One must keep in mind that AR was just one aspect of the teaching framework proposed [49]
Age Restrictions	Age restrictions related to limited AR participation	The authors in [33] identified barriers of entry based on age and lowered the age group to include younger participants 14 – 18
Technical Issues	Technical issues related to the use of technology and AR that might have interrupted the learning experience	"Ensuring that all mobile devices were adequately prepared for the visit, including checking battery levels and the operational use of the required applications. This indicates potential issues with device readiness and technical reliability during the activity" [50]

Interruptions during AR activities, for instance when teachers provide instructions or guidance to students, seemed to impact on their immersive experience and disrupt the flow of learning and engagement [33, 65]. In addition, difficulties of participants initiating AR games and navigating digital interfaces within the educational context were also reported [74]. On the other hand, AR was considered a *distraction* rather than a learning aid in some cases. The study of [73], suggested that active interaction with AR models might divert attention from core learning objectives, such as reading or listening to instructional content, while the study by [67], highlighted that when unlimited hints are provided in AR activities, they can shortcut the learning process, undermine deeper understanding, and distract students from the main educational tasks.

Technical issues were also reported, such as image marker reliability and device readiness [50]. AR tracking relies on image marker reliability, raising concerns about the reliability of virtual object placement in real environments [66]. Connectivity issues and ensuring that all necessary devices are adequately prepared for AR activities were found to affect the accessibility and adoption of AR for story-related activities [50, 83].

The need for a high level of technical knowhow also highlights the *complexity of developing AR content*. A good example is the study of [57], who described the extensive use of software tools for character design, animation, and scene integration, highlighting the technical know-how needed for AR development.

Substantial *time investment* was found to be required for AR for story-related activities, as evidenced by [49], who noted a 3.5-month period for integrating the AR intervention in the educational context, as well as by [79] that mentioned a certain amount of time for organizing material and scenarios for escape classroom or games. The study of [59] highlighted the importance of the simplicity of AR tools in classroom settings. The ease of integration allows AR to seamlessly blend into daily educational routines, making advanced technology accessible and practical for regular use. *Age restrictions* may also be related to limited AR participation, as discussed by [33].

3.3 Benefits to the adoption of AR for story-related activities (RQ3)

AR holds potential for revolutionizing various aspects of education and entertainment. Lots of benefits have been reported in the literature to date, as elaborated further below. Table 10 presents the identified benefits and details on how they were coded through the manuscripts.

Yet, AR has been shown to create more *inclusive and engaging story experiences* across diverse educational settings [53, 63, 75] through the enhancement of traditional materials such as storybooks [63, 84]. AR entails potential in enhancing engagement and motivation through gamification and interactive narratives, making learning processes not only more enjoyable but also more effective [55, 61, 65, 79]. Historical narratives were found to be more engaging and immersive with the use of AR, which can engage students more deeply with educational content through interactive storytelling that stimulates creativity [49, 69]. The studies of [72, 76] further demonstrated AR's and digital storytelling effectiveness in cultural education, enhancing interaction with cultural heritage. Another study used storytelling techniques within the context of AR to create a dynamic and engaging experience for children, enhancing their motivation and coping mechanisms [82].

Table 10 Identification and coding of the benefits related to the adoption of AR for story-related activities

Theme	Description	Examples from the reviewed manuscripts
Inclusive and engaging story experiences	AR creates more inclusive and engaging story experiences across diverse educational settings	In [49] it was acknowledged that the presentation and interaction of 3D animations provided by AR attracted the interest of children with ASD In [79], the authors support that AR systems are also effective tools to motivate children towards learning content
Linking digital and physical learning environments	AR enhances the overall learning experience by making storytelling more dynamic and interactive by linking digital and physical learning environments	Students produced digital museum tutorials with recordings with the use of AR followed by an educational visit at the museum. They were first tour-guided in the museum and then allowed to move and work autonomously for the activity implementation [50]
Improves vocabulary and narrative skills	AR can improve vocabulary and narrative skills across a variety of languages	The results in the study of [51] showed that learners using an integrated approach of ARPBA (Augmented Reality Place-Based Approach) created better stories, developed learners' narrative skills and expanded their vocabulary repertoire
Higher engagement levels	AR promotes higher engagement levels among students with varied comprehension skills	In [77], participants used an AR serious game which they found easy, useful, and expressed the desire to play it again indicating their thorough engagement
Development of social skills	AR can contribute to the development of social skills for students with ASD	In [57], children with ASD were able to learn social interaction behavior in the AR system and use simple and easy to carry tablet tools to achieve good interaction
Development of twenty-first century skills	AR can contribute to the development of twenty-first century skills	In [52], the process of designing an AR artifact developed students' ability to collaborate, evaluate and problem-solve
Supports knowledge consolidation	AR can support knowledge consolidation over time	In [52] students engaged in AR creation projects that helped them practice and consolidate learned knowledge and skills over time

AR enhances the overall learning experience by making storytelling more dynamic and interactive by linking *digital and physical learning environments*. It allows, for example, uploading museum exhibits' photos in AR that students can use to develop digital tutorials along with recordings and additional information [50]. Students in AR can engage with story-related activities at their own pace and practice independently in a stress-free environment that enhances learning outcomes [66, 70] and creates a unique storytelling experience.

The versatility of AR in language education was emphasized. AR can *improve vocabulary and narrative skills* across a variety of languages [51, 71]. For instance, positive impact on Arabic language learning among students in Palestine were reported in the study of [68]. Likewise, AR promotes *higher engagement levels* among students with varied comprehension skills [73, 74] and can contribute to the *development of social skills* for students with ASD [57].

In addition, the use of AR in story-related activities contributes to the *development of 21st century skills* (e.g., collaboration, problem-solving, digital literacy), as evidenced from the papers included in this review [52, 53]. For instance, in [52] students through the creation of their AR artifact significantly improved their digital literacy abilities, collaboration, communication, creation, evaluation and problem-solving skills. Finally, AR combined with story-related activities can support *knowledge consolidation* [52, 83] since it facilitates understanding, therefore aids information retention and knowledge consolidation.

4 Discussion

This systematic literature review aimed to inform educators and researchers on good learning design practices in the use of AR for story-related activities (e.g., story creation, storytelling) in different content domains. The analysis of the 39 studies reveals several significant trends and insights into the current use of AR in primary and secondary education, which are discussed below.

4.1 Current practices of learning design pertaining to the use of AR for story-related activities

With respect to the first research question of this study, it was found that common practices of learning design pertaining to the use of AR for story-related activities include creating digital stories with AR, adding interactive components to storybooks, and guiding students to story-building activities where they can see and interact with story and multimodal elements in AR.

AR story-related activities were employed across various domains, ranging from mathematics to history and special education. An interesting finding is that studies on the use of AR and story-related activities for language learning showed increased interest. The primary objective of using AR in story-related activities has often focused on enhancing engagement, creativity, and understanding complex concepts through interactive and immersive experiences. Such experiences seemed to be beneficial for vocabulary

acquisition and reading comprehension. This finding seems to be consistent with earlier systematic literature studies that support that the favored language skills for AR technology included word identification, word meaning and spelling comprehension, and word pronunciation, all of which needed lower cognitive abilities [85]. Similarly, our findings further support the affordances of AR in education and language learning, as previously highlighted in a literature review (e.g., [86]). Another finding is that game-based elements raise motivation and engagement levels and are proven to enhance learning in domains like social skills and mathematics when integrated into AR story related activities and indicate the potential of using AR to improve social skills, particularly among children with ASD.

In terms of task design, this review has demonstrated three types of activities: (a) information transmission tasks that allow students to access AR multimedia story elements; (b) social constructivist activities, in which students main tasks were to carry out story-related closed-ended quizzes, games, or missions, engaging in discussion and social interaction with animated 3D character(s) of a storybook while receiving AR multimedia content and feedback; and (c) constructivist/ionist tasks in which learners engaged in the creation of story-related AR artefacts (e.g., stories, narrations). Overall, AR for story-related activities entails the potential to deliver a dynamic and engaging learning environment by combining collaborative, constructivist, and experiential learning approaches and methodologies with advanced digital tools and clearly stated learning objectives. Previous studies also support the integration of digital storytelling with project-based learning to improve students' learning motivation and performance [8].

4.2 Barriers of the adoption of AR for story-related activities

This study's second research question aimed to identify barriers that hinder the widespread use of AR for story-related activities in both primary and secondary schools. The barriers refer to technical difficulties such as the requirement for dependable internet access, the accessibility of AR-capable devices, as well as the level of technical expertise needed to develop and use AR content. It is important to note here that this is a regular case in many schools, particularly in underfunded districts, where they may face barriers in providing access to the required hardware (e.g., smartphones, tablets, laptops or AR glasses), which limits the widespread adoption of AR for educational purposes. Additionally, barriers in the use of AR for story-related activities include interruptions during AR-activities or AR being a distraction rather than a learning aid. That said, the study findings suggest that while some students show increased motivation and improved understanding of content, others may struggle with the technology itself, resulting in a potentially distracted or disengaged experience. Another finding is that pedagogical issues also exist, such as a deficiency in teacher preparation, the complexity in the development of AR content, as well as assistance and challenges connecting AR activities to learning goals and curriculum requirements. Previous reviews on the use of AR in education identified similar barriers including high costs, technical issues, curriculum design challenges and negative attitudes [87]. Addressing the barriers related to the use of AR with story-related activities is essential for realizing the full potential of AR technology with AR stories in educational contexts. By overcoming technical challenges, minimizing interruptions, and optimizing content quality, AR can optimize immersive and effective learning experiences.

4.3 Benefits of using AR for story-related activities

Despite the barriers of using AR for story-related activities, several benefits were also identified in this study that came to answer the third research question. The benefits of AR for story-related activities include its potential to develop more inclusive and engaging experiences and support narrative skills through students' engagement with storytelling. In accordance with the present results, the study of [88] who used a mobile application to investigate English as a foreign language writing skills in connection to self-experience in a real-world learning setting, showed that the use of authentic materials in storytelling activities motivates students to share their experiences, improves their language writing skills and also enhances their confidence to use foreign language in real situations. Traditional storytelling can be static and passive, where students simply listen or read. By using AR applications and overlaying digital information on the physical learning environment, storytelling can become a more dynamic experience. Additionally, AR for story-related activities can provide an engaging and stimulating learning environment that makes abstract concepts more tangible and supports the development of 21st century skills. Previous studies also support that the effective use of AR in lessons can positively affect 21st-century skills such as innovation and creativity, critical thinking, problem solving, as well as communication and collaboration and communication [89]. Moreover, the use of AR with story-related activities offers a multi-sensory learning experience and keeps students immersed in a story, aiding to knowledge consolidation [90].

When stories are brought to life using AR, students frequently exhibit greater motivation and a deeper comprehension of the topic. This is consistent with other systematic and meta-analysis research that showed using AR to enhance language or social studies learning could be linked with greater learning motivation or attitude [4, 91, 92]. These findings suggest that the combination of story-related activities with AR provides a useful educational tool that can support students in different contexts.

4.4 Future directions for research and practice in AR for story-related activities

Based on the findings from the papers reviewed, some implications for researchers and practitioners were extracted and are presented in this section.

4.4.1 Document learning design

Findings from this review did not clearly help to identify the best practices for learning experience design in the context of AR story-related activities. This is because most of the studies lacked detailed descriptions on how the AR story-related activities were implemented in the educational context (e.g., number of devices available, classroom orchestration, description of the AR implementation step by step, time required for preparation, implementation, evaluation, etc.). In this review, a learning design framework guided the coding of papers and synthesis of this review in terms of tools, ingredients, and techniques [41]. Yet, it was not always possible to find these details in the papers, especially how the interplay of tools, ingredients, and techniques came to support the enactment of a successful learning experience. For example, aligning AR-enhanced learning activities more closely with official curricula could ensure that such methods are not just supplementary, but instead become integral to educational strategies and lesson planning. Yet, very little was covered in the reviewed articles as to how curriculum integration was done. This lack of details in classroom interventions is also supported by previous systematic reviews noting the need for criteria for selecting specific tools for supporting story-related activities as well as the need for detailed school curricula for effectively combining digital storytelling [4, 40]. The authors of the current review are calling researchers and practitioners for action in this direction. Further research is needed to identify the best practices on the learning (experience) design when it comes to the use of AR for story-related activities in primary and secondary education settings.

4.4.2 Work on teachers' readiness level as learning designers

Teachers must not see themselves only as users and consumers of AR tools. They must be ready to design meaningful AR experiences for their students. This does not mean simply informing teachers on the affordances of different AR software or applications or giving them pre-packed materials and resources but also developing the literacies for designing such resources to meet their needs. Teachers' preparation also involves the planning of an AR-driven story-related activity in order to provide a meaningful learning experience to students without disruption. This means providing clear instructions before students engage with AR, as well as preparatory activities to familiarise them with the technology to avoid interruptions while students are engaged with AR. Teachers need to plan for both individual and collaborative AR story-related tasks in small groups or pairs in order to give all students the opportunity to stay engaged by e.g., creating or narrating a story, solving problems, answering to story-related quizzes through AR and accessing AR content for various learning domains. The integration of collaborative tasks in story-related activities, the reduction of distraction by displaying only the main content in the tool and the familiarity with the tool were also identified as good design practices in previous studies for keeping students motivated (e.g., [8, 40]). Once again, the authors of this review are calling for action in this direction, which appears to be under researched. It is, therefore, important to provide ongoing guidance and support to educators to optimise the use of AR in teaching and learning [51, 84]. Such guidance can be incorporated in professional development as well as teacher preparation programs so that the teachers get prepared to effectively use AR technologies in their classrooms [74]. Within a story-related activity, the role of teachers may vary from designer of the AR story-related content or as a facilitator of students' story-related constructions. Consistent with the last idea, the present study indeed emphasises looking at students as creators of their own AR stories, which puts teachers in a position to design such learning experiences.

4.4.3 Engage multiple stakeholders

The collaboration and consideration of diverse relevant stakeholders' perspectives and preferences, such as students, teachers, learning designers, technologists/technicians, researchers, schools as entities, and policymakers, is important to ensure successful exploitation of AR in teaching and learning. As [31] have argued, policymakers

Fig. 2 Summary of responses to RQs

must consider the effective, institution-wide deployment of AR technologies to realise their full potential in educational settings. This is also directly in line with the need for improved technological platforms to overpass the previously reported technical issues in almost all the reviewed studies. It is important that the AR tools are easy to use by both educators and students, and for this to occur, there is a pressing need for collaboration amongst all stakeholders. Exploiting AR in teaching and learning cannot be an endeavour by an educator or a researcher. Echoing and extending [31], we would argue that institution-wide deployment of tools requires the engagement of all stakeholders.

5 Conclusions

The use of AR in story-related activities in primary and secondary school is summarised along with the benefits, barriers, and future directions. This work provides a better understanding of the current practices on the use of AR with story-related activities in different domains, ranging from mathematics and special education to language learning. Figure 2 summarises the answers to research questions examined through this systematic literature review.

Ultimately, this review highlights that AR entails the potential to upgrade story-related tasks and activities through the use of AR-enhanced storybooks or even through the engagement of students in maker-based storytelling with the use of AR and create a unique storytelling experience. The affordance of AR to place the narrative in the physical space allows learners to place the characters of their stories in their context. Moreover, immediate feedback provided in AR promotes autonomous and active learning for students, while the teacher becomes the facilitator of the learning experience. When an AR story-related experience is well-planned ahead and is well-integrated in the lessons, students are provided with meaningful and engaging learning experiences that enhance their collaboration with peers and improve their learning skills. This review has also provided

implications for researchers and educators that mainly highlight the need to build synergies between research and practice that will eventually optimise the design of evidence-based experiences.

5.1 Limitations

A potential limitation of the present review is that the scope may be too narrow, focusing on the use of AR in story-related activities in primary and secondary education. Although this narrow scope largely informs the present study, some of the reported findings may not reflect other educational contexts. Nevertheless, we do believe that the extracted recommendations, based on the careful reading of the details of these manuscripts, probably hold true in regard to the overall use of AR in teaching and learning as reflected in today's literature.

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Declarations

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References

1. Wu, J., Chen, D.T.V.: A systematic review of educational digital storytelling. Comput. Educ. **147**, 103786 (2020). https://doi.org/10.1016/J.COMPEDU.2019.103786
2. Lucarevschi, C. R.: The role of storytelling in language learning: a literature review, 2016
3. Maureen, I.Y., van der Meij, H., de Jong, T.: Evaluating storytelling activities for early literacy development. Int. J. Early Years Educ. **30**, 679–696 (2022). https://doi.org/10.1080/09669760.2021.1933917
4. Palioura, M., Sapounidis, T.: Storytelling and educational robotics: a scoping review (2004–2024). Comput. Educ. **225**, 105186 (2025). https://doi.org/10.1016/j.compedu.2024.105186
5. Stewart, K.D., Ivala, E.: Silence, voice, and "other languages": digital storytelling as a site for resistance and restoration in a South African higher education classroom. Br. J. Educ. Technol. **48**, 1164–1175 (2017). https://doi.org/10.1111/BJET.12540
6. Stewart, K., Gachago, D.: Being human today: a digital storytelling pedagogy for transcontinental border crossing. Br. J. Educ. Technol. **47**, 528–542 (2016). https://doi.org/10.1111/BJET.12450
7. Tsou, W., Wang, W., Tzeng, Y.: Applying a multimedia storytelling website in foreign language learning. Comput. Educ. **47**, 17–28 (2006). https://doi.org/10.1016/J.COMPEDU.2004.08.013
8. Quah, C.Y., Ng, K.H.: A systematic literature review on digital storytelling authoring tool in education: January 2010 to January 2020. Int. J. Hum. Comput. Interact. **38**, 851–867 (2022). https://doi.org/10.1080/10447318.2021.1972608
9. Barrett, H.: Researching and Evaluating Digital Storytelling as a Deep Learning Tool. In: Crawford, C., Carlsen, R., McFerrin, K., et al. (eds.) Society for Information Technology & Teacher Education International Conference 2006, pp. 647–654. Association for the Advancement of Computing in Education (AACE), Orlando, Florida, USA (2006)
10. Lim, N.Z.L., Zakaria, A., Aryadoust, V.: A systematic review of digital storytelling in language learning in adolescents and adults. Educ. Inf. Technol. **27**, 6125–6155 (2022). https://doi.org/10.1007/S10639-021-10861-0
11. Khan, S., Ziden, A.A., Khan, A.B.B.M.A.: A systematic literature review of digital storytelling for English language speaking and writing skills. Commun. Comput. Inf. Sci. **1916**, 134–151 (2023). https://doi.org/10.1007/978-3-031-44581-1_11/TABLES/4
12. Robin, B.R.: The effective uses of digital storytelling as a teaching and learning tool. Handbook Res. Teac. Literacy Through Commun. Visual Arts: Volume II **2**, 429–440 (2015). https://doi.org/10.4324/9781315759616-57/EFFECTIVE-USES-DIGITAL-STORYTELLING-TEACHING-LEARNING-TOOL-BERNARD-ROBIN
13. Irwin, B.: Smartphones as pedagogical tools: transforming analog classrooms through digital storytelling. JALTCALL Publications 32–41. (2024) https://doi.org/10.37546/jaltsig.call.pcp2023-04
14. Hourcade, J. P., Bederson, B. B., Druin, A., Taxén, G., KidPad: collaborative storytelling for children. CHI '02 Extended Abstracts on Human Factors in Computing Systems (CHI EA '02) 500–501. (2002) https://doi.org/10.1145/506443.506449

15. Benford, S., Bederson, B. B., Åkesson, K. P., et al: Designing storytelling technologies to encourage collaboration between young children. Conference on Human Factors in Computing Systems—Proceedings 556–563. (2000) https://doi.org/10.1145/332040.332502/SUPPL_FILE/01_00_DESIGNING_STORYTELLING.MP4
16. Hava, K.: Exploring the role of digital storytelling in student motivation and satisfaction in EFL education. Comput. Assist. Lang. Learn. **34**, 958–978 (2021). https://doi.org/10.1080/09588221.2019.1650071
17. Valguarnera, S., Landoni, M.: "This book is magical!": exploring emergent readers' preferences and wishes for storytelling tools. ACM Int. Conf. Proceedi. Series (2022). https://doi.org/10.1145/3546155.3547274
18. Isaacs, M.A., Tondeur, J., Howard, S., et al.: Digital storytelling as a strategy for developing 21st-century skills: a systematic review of qualitative evidence. Technol. Pedagog. Educ. (2024). https://doi.org/10.1080/1475939X.2024.2343929
19. Sagri, M., Sofos, F., Mouzaki, D.: Digital storytelling, comics and new technologies in education: review, research and perspectives. Int. Edu. J. Comparat. Perspect. **17**, 97–112 (2018)
20. Anderson, J., Chung, Y.C., Macleroy, V.: Creative and critical approaches to language learning and digital technology: findings from a multilingual digital storytelling project. Lang. Educ. **32**, 195–211 (2018). https://doi.org/10.1080/09500782.2018.1430151
21. Jason, O.: Digital storytelling in the classroom : new media pathways to literacy, learning, and creativity. Corwin Press (2008)
22. Spencer, T.D., Pierce, C.: Classroom-based oral storytelling: reading, writing, and social benefits. Read. Teach. **76**, 525–534 (2023). https://doi.org/10.1002/TRTR.2144
23. Du, I.-I., Nguyen, T.M., Le, T.N.: Improving first-year English-majored students' speaking skills through using digital storytelling. Int. J. Lang. Instr. **3**, 29–44 (2024). https://doi.org/10.54855/IJLI.24323
24. Sembiring, L.B., Simajuntak, D.C.: Digital storytelling as an alternative teaching technique to develop vocabulary knowledge of EFL learners. J. Lang. Lang. Teach. **11**, 211–224 (2023). https://doi.org/10.33394/JOLLT.V11I2.7523
25. Arroba, J., Acosta, H.: Authentic digital storytelling as alternative teaching strategy to develop speaking skills in EFL classes. LEARN J. Language Educat. Acquisition Res. Netw. **14**, 317–343 (2021)
26. Robin, B.R.: Digital storytelling: a powerful technology tool for the 21st century classroom. Theory Pract. **47**, 220–228 (2008). https://doi.org/10.1080/00405840802153916
27. Sarıca, H.Ç.: Emotions and digital storytelling in the educational context: a systematic review. Rev. Educ. **11**, e3430 (2023). https://doi.org/10.1002/REV3.3430
28. Cuendet, S., Bonnard, Q., Do-Lenh, S., Dillenbourg, P.: Designing augmented reality for the classroom. Comput. Educ. **68**, 557–569 (2013). https://doi.org/10.1016/J.COMPEDU.2013.02.015
29. Garzón, J., Pellas, N., Söbke, H., et al.: An overview of twenty-five years of augmented reality in education. Multimodal Technol. Interact. (2021). https://doi.org/10.3390/MTI5070037
30. Shadiev, R., Liang, Q.: A review of research on AR-supported language learning. Innov. Lang. Learn. Teach. **18**, 78–100 (2024). https://doi.org/10.1080/17501229.2023.2229804
31. Mystakidis, S., Fragkaki, M., Filippousis, G.: Ready teacher one: Virtual and augmented reality online professional development for k-12 school teachers. Computers (2021). https://doi.org/10.3390/computers10100134
32. López-Belmonte, J., Moreno-Guerrero, A.J., López-Núñez, J.A., Hinojo-Lucena, F.J.: Augmented reality in education. A scientific mapping in Web of Science. Interact. Learn. Environ. **31**, 1860–1874 (2023). https://doi.org/10.1080/10494820.2020.1859546
33. Glenn, T., Ipsita, A., Carithers C., et al: (2020) StoryMakAR: Bringing Stories to Life with An Augmented Reality & Physical Prototyping Toolkit for Youth. In: Conference on Human Factors in Computing Systems—Proceedings. Associat. Comput. Mach.
34. Yilmaz, R.M., Goktas, Y.: Using augmented reality technology in storytelling activities: examining elementary students' narrative skill and creativity. Virtual Real **21**, 75–89 (2017). https://doi.org/10.1007/s10055-016-0300-1
35. Panhale, T., Bryce, D., Tsougkou, E.: Augmented reality and experience co-creation in heritage settings. J. Mark. Manag. **39**, 470–497 (2023). https://doi.org/10.1080/0267257X.2022.2120061
36. Cheng, K.H.: Reading an augmented reality book: an exploration of learners' cognitive load, motivation, and attitudes. Australas. J. Educ. Technol. **33**, 53–69 (2017). https://doi.org/10.14742/AJET.2820
37. Kisno, Wibawa, B., Khaerudin,: Digital Storytelling for Early Childhood Creativity: Diffusion of Innovation "3-D Coloring Quiver Application Based on Augmented Reality Technology in Children's Creativity Development". Int. J. Online Biomed. Eng. **18**:26–42. (2022) https://doi.org/10.3991/ijoe.v18i10.32845
38. Zhang, L., Kim, D., Cho, Y., et al: Jigsaw: Authoring Immersive Storytelling Experiences with Augmented Reality and Internet of Things. In: Conference on Human Factors in Computing Systems—Proceedings. Associat. Comput. Mach. (2024)
39. Samad Danish, A., Noor, N., Hamid, Y., et al: Augmented Narratives: Unveiling the Efficacy of Storytelling in Augmented Reality Environments. J. Xi'an Shiyou University (2024)
40. Ng, D.T.K., Lai, W.Y.W., Yung, J.M.S., Ng, C.W.: Using cospaces in augmented reality digital story creation: A thematic analysis. Comput. Edu.: X Reality. (2024). https://doi.org/10.1016/j.cexr.2024.100090
41. Wasson, B., Kirschner, P.A.: Learning design: European approaches. TechTrends **64**, 815–827 (2020). https://doi.org/10.1007/s11528-020-00498-0
42. Page, M.J., McKenzie, J.E., Bossuyt, P.M., et al.: The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. The BMJ (2021). https://doi.org/10.1136/bmj.n71
43. Lai, J.W.M., Bower, M.: Evaluation of technology use in education: findings from a critical analysis of systematic literature reviews. J. Comput. Assist. Learn. **36**, 241–259 (2020). https://doi.org/10.1111/JCAL.12412
44. Novak, E., Razzouk, R., Johnson, T.E.: The educational use of social annotation tools in higher education: a literature review. Internet High. Educ. **15**, 39–49 (2012). https://doi.org/10.1016/J.IHEDUC.2011.09.002
45. Gao, F., Luo, T., Zhang, K.: Tweeting for learning : a critical analysis of research on microblogging in education published in 2008-2011. Br. J. Educ. Technol. **43**, 783–801 (2012). https://doi.org/10.1111/J.1467-8535.2012.01357.X
46. Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al: PRISMA_2020_flow_diagram_new_SRs_v1. BMJ **372** (2017)
47. García-Holgado, A., Marcos-Pablos, S., García-Peñalvo, F.: Guidelines for performing systematic research projects reviews. Int. J. Interact. Multimed. Artif. Intell. **6**, 9 (2020). https://doi.org/10.9781/ijimai.2020.05.005
48. Spolaôr, N., Benitti, F.B.V.: Robotics applications grounded in learning theories on tertiary education: a systematic review. Comput. Educ. **112**, 97–107 (2017). https://doi.org/10.1016/j.compedu.2017.05.001
49. Lee, I.J., Hsu, H.T.: Applied the augmented reality technology combined with social stories strategies and computational thinking games to improve the social skills of children with ASD. Interact. Learn. Environ. (2023). https://doi.org/10.1080/10494820.2023.2258942

50. Rammos, D., Bratitsis, T.: Museum Exhibits that Interact with Pupils' Mobile Devices. The Case of Hellenic Maritime Museum. In: Advances in Intelligent Systems and Computing. Springer Science and Business Media Deutschland GmbH, pp 189–201 (2021)
51. Mpiti, P.T., Makena, B., Qoyi, M.: Augmented reality for teaching storytelling in a rural foundation phase primary school: integrating a place-based approach. Res. Soc. Sci. Technol. **8**, 105–118 (2023). https://doi.org/10.46303/ressat.2023.24
52. Hsu, H.P., Wenting, Z., Hughes, J.E.: Developing elementary students' digital literacy through augmented reality creation: insights from a longitudinal analysis of questionnaires, interviews, and projects. J. Educ. Comput. Res. **57**, 1400–1435 (2019). https://doi.org/10.1177/0735633118794515
53. Stylianidou, N., Sofianidis, A., Manoli, E., Meletiou-Mavrotheris, M.: "Helping Nemo!"—Using Augmented Reality and Alternate Reality Games in the Context of Universal Design for Learning. Educ Sci (Basel) (2020). https://doi.org/10.3390/educsci10040095
54. Sousa, A. M., Romão, T.: Encouraging chemistry learning through an augmented reality magic game. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Science and Business Media Deutschland GmbH, pp 12–21 (2021)
55. Korosidou, E., Bratitsis, T., Gamifying early foreign language learning: using digital storytelling and augmented reality to enhance vocabulary learning. In: Advances in Intelligent Systems and Computing. Springer Science and Business Media Deutschland GmbH, pp 726–737 (2021)
56. Lee, I.-J.: Augmented reality coloring book: an interactive strategy for teaching children with autism to focus on specific nonverbal social cues to promote their social skills. Int. Stud. Soc. Behaviour Commun. Biol. Artif. Syst. **20**, 256–274 (2019). https://doi.org/10.1075/is.18004.lee
57. Hsu, H. T., Lee, I. J.: Using augmented reality technology with serial learning framework to develop a serial social story situation board game system for children with autism to improve social situation understanding and social reciprocity skills. In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer, pp 3–18 (2020)
58. Kumpulainen, K., Byman, J., Renlund, J., Wong, C.C.: Children's augmented storying in, with and for nature. Educ Sci (Basel) (2020). https://doi.org/10.3390/educsci10060149
59. Chiazzese, G., Tosto, C., Seta, L., et al Combining Augmented Reality and Fairy Tales to Teach Science to Primary School Students: Teachers' Experience from the Fairy Tale Science Augmented (FAnTASIA) Project. In: Communications in Computer and Information Science. Springer Science and Business Media Deutschland GmbH, pp 706–718 (2023)
60. Câmara Olim, S., Nisi, V., Romão, T.: Periodic fable discovery: an augmented reality serious game to introduce and motivate young children towards chemistry. Multimed. Tools Appl. **83**, 52593–52619 (2024). https://doi.org/10.1007/s11042-023-17526-9
61. Zuo, T., Jiang, J., Van der Spek, E., et al.: Situating learning in AR fantasy, design considerations for AR game-based learning for children. Electronics (2022). https://doi.org/10.3390/electronics11152331
62. Song, E., Suaib, N. M., Sihes, A. J., et al Design and development of learning mathematics game for primary school using handheld augmented reality. In: IOP Conference Series: Materials Science and Engineering. IOP Publishing Ltd (2020)
63. Pegrum, M.: Augmented reality learning: education in real-world contexts. Research-publishing.net (2021)
64. Şimşek, B., Direkçi, B.: The effects of augmented reality storybooks on student's reading comprehension. Br. J. Educ. Technol. **54**, 754–772 (2023). https://doi.org/10.1111/bjet.13293
65. Danaei, D., Jamali, H.R., Mansourian, Y., Rastegarpour, H.: Comparing reading comprehension between children reading augmented reality and print storybooks. Comput. Educ. (2020). https://doi.org/10.1016/j.compedu.2020.103900
66. Besa, M. S.: Mga Kwento ni Lola Basyang: An Augmented Reality on Selected Philippine Folklore. In: 2021 IEEE 13th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management, HNICEM 2021. Institute of Electrical and Electronics Engineers Inc. (2021)
67. Binhomran, K., Altalhab, S.: The impact of implementing augmented reality to enhance the vocabulary of young EFL learners. JALT CALL J. **17**, 23–44 (2021). https://doi.org/10.29140/JALTCALL.V17N1.304
68. Sorrentino, F., Spano, L.D.: Post-it notes: supporting teachers in authoring vocabulary game contents. Multimed. Tools Appl. **78**, 23049–23074 (2019). https://doi.org/10.1007/s11042-019-7604-6
69. Al Rajab, M., Odeh, S., Hazboun, S., Alheeh, E.: AI-Powered Smart Book: Enhancing Arabic Education in Palestine with Augmented Reality. In: Lecture Notes in Networks and Systems. Springer Science and Business Media Deutschland GmbH, pp 167–178 (2023)
70. Wu, Q., Wang, W., Liu, Q., et al Tidd: Augmented Tabletop Interaction Supports Children with Autism to Train Daily Living Skills. In: Proceedings - SIGGRAPH 2023 Posters. Association for Computing Machinery, Inc (2023)
71. Lee, I.J.: Kinect-for-windows with augmented reality in an interactive roleplay system for children with an autism spectrum disorder. Interact. Learn. Environ. **29**, 688–704 (2021). https://doi.org/10.1080/10494820.2019.1710851
72. Bursali, H., Yilmaz, R.M.: Effect of augmented reality applications on secondary school students' reading comprehension and learning permanency. Comput. Human Behav. **95**, 126–135 (2019). https://doi.org/10.1016/j.chb.2019.01.035
73. del Río Guerra, M.S., Martínez, A.E.G., Martin-Gutierrez, J., López-Chao, V.: The limited effect of graphic elements in video and augmented reality on children's listening comprehension. Appl. Sci. (Switzerland) (2020). https://doi.org/10.3390/app10020527
74. Estudante, A., Dietrich, N.: Using augmented reality to stimulate students and diffuse escape game activities to larger audiences. J. Chem. Educ. **97**, 1368–1374 (2020). https://doi.org/10.1021/acs.jchemed.9b00933
75. Yangin Ersanli, C.: The effect of using augmented reality with storytelling on young learners' vocabulary learning and retention. Novitas-ROYAL (Res. Youth and Language) **17**, 62–72 (2023)
76. Ntagiantas, A., Manousos, D., Konstantakis, M., et al: Augmented Reality children's book for intangible cultural heritage through participatory content creation and promotion. Case study: The pastoral life of Psiloritis as a UNESCO World Geopark. In: SMAP 2021 - 16th International Workshop on Semantic and Social Media Adaptation and Personalization. Institute of Electrical and Electronics Engineers Inc. (2021)
77. Camara, S., Nisi, V., Romão, T.: Enhancing children spatial skills with augmented reality serious games. In: CHI PLAY 2021 - Extended Abstracts of the 2021 Annual Symposium on Computer-Human Interaction in Play. Association for Computing Machinery, Inc, pp 94–100 (2021)
78. Ntagiantas, A., Konstantakis, M., Aliprantis, J., et al.: An augmented reality children's book edutainment through participatory content creation and promotion based on the pastoral life of Psiloritis. Appl. Sci. (2022). https://doi.org/10.3390/app12031339

79. Câmara Olim, S. M., Nisi, V., Rubegni, E., Periodic Fable Augmenting Chemistry with Technology, Characters and Storytelling. In: Proceedings of Interaction Design and Children, IDC 2022. Association for Computing Machinery, Inc, pp 123–136 (2022)
80. Bremner, L., Fabricatore, C., Europa Hochschule, E. H. E., et al; A framework system for the design of a digital augmented-reality pretend play activity for children with ASD. In: Proceedings of the 14th European Conference on Games Based Learning ECGBL (2020)
81. Nasruddin, Z. A., Mohd Ariffin, N. H., Abdul Rashid, N. S., Mazlin, I., MYbody: Augmented Reality Mobile App for Understanding Body Boundaries Using MADLC. In: Proceedings - 2023 10th International Conference on Electrical and Electronics Engineering, ICEEE 2023. Institute of Electrical and Electronics Engineers Inc., pp 200–206 (2023)
82. Chanlin, L.J.: Augmented reality for supporting adult-child shared reading. Libri **71**, 251–265 (2021)
83. Castro Pacheco, M. L., Calle Loja, M., Segarra Chalco, M.: Storytelling as a Motivational Resource in the Therapy of Childhood Cancer. In: Lecture Notes in Networks and Systems. Springer Science and Business Media Deutschland GmbH, pp 311–324 (2023)
84. Singh, M., Bangay, S., Grossek, H., Sajjanhar, A.: Forest classroom: a case study of educational augmented reality design to facilitate classroom engagement. Multimodal Technol. Interact. (2023). https://doi.org/10.3390/mti7050046
85. Majid, S.N.A., Salam, A.R.: A systematic review of augmented reality applications in language learning. Int. J. Emerg. Technol. Learn. **16**, 18–34 (2021). https://doi.org/10.3991/ijet.v16i10.17273
86. Parmaxi, A., Demetriou, A.A.: Augmented reality in language learning: a state-of-the-art review of 2014–2019. J. Comput. Assist. Learn. **36**, 861–875 (2020). https://doi.org/10.1111/jcal.12486
87. Albishri, B., Blackmore, K.L.: Duality in barriers and enablers of augmented reality adoption in education: a systematic review of reviews. Interact. Technol. Smart Educat. **22**, 167–191 (2025). https://doi.org/10.1108/ITSE-10-2023-0194/FULL/PDF
88. Nguyen, T.H., Hwang, W.Y., Pham, X.L., Pham, T.: Self-experienced storytelling in an authentic context to facilitate EFL writing. Comput. Assist. Lang. Learn. **35**, 666–695 (2022). https://doi.org/10.1080/09588221.2020.1744665
89. Dilmen, I., Atalay, N.: The effect of the augmented reality applications in science class on students' 21st century skills and basic skills. J. Sci. Learn. **4**, 337–346 (2021). https://doi.org/10.17509/jsl.v4i4.32900
90. Alhebaishi, S., Stone, R.: Augmented Sensory Experience and Retention: ASER Framework. Int. J. Adv. Comput. Sci. Appl. **16**, 2025 (2025)
91. Chang, H.Y., Binali, T., Liang, J.C., et al.: Ten years of augmented reality in education: a meta-analysis of (quasi-) experimental studies to investigate the impact. Comput. Educ. (2022). https://doi.org/10.1016/j.compedu.2022.104641
92. Huang, X., Zou, D., Cheng, G., Xie, H.: A systematic review of AR and VR enhanced language learning. Sustainability (Switzerland) **13**, 1–28 (2021). https://doi.org/10.3390/su13094639